Bottom line: $1\mu A$ ok
$10 \mu A$ danger!
$100 \mu A$ need new design

Bob Michaels July 11,

Beam Heating

1mm thick tungsten (W) target for e^+ prod.

$I = 1 \mu A$

$P = t \, \rho \, \frac{dE}{dx} \, I$

$= 0.1 cm * 19.3 \frac{g}{cm^3} * 1.145 \frac{MeV}{g/cm^2} * 1 \mu A$

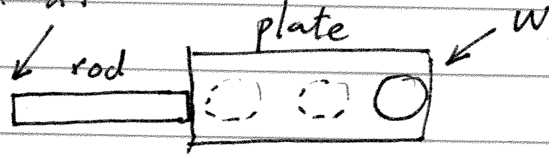
$P = 2.2 W$ power in target

Note: $1 MeV * \frac{10^6 eV}{MeV} * 1 \mu A * \frac{10^{-6} A}{\mu A}$

$* 1.6 * 10^{-19} \frac{J}{eV} * \frac{1 e^-}{1.6 * 10^{-19} C} = 1 W$

Ladder conductivity

fixed 27°



$\Delta T = \Delta T_1 + \Delta T_2$

$P = \frac{K_i A_i \Delta T_i}{L_i}$

Assume $\frac{1}{4}" \phi$ 6" long ~.5" wide (effective) * $\frac{1}{8}$" thick 6" long

$\Delta T_i = \frac{P L_i}{K_i A_i}$

rod	plate
ΔT_1	ΔT_2

$\Rightarrow \Delta T = P \sum_i \frac{L_i}{K_i A_i}$

		rod	plate
length	L_i	15.2	15.2 cm
conductivity	K_i	2.2	2.2 $\frac{W}{cm K}$
area	A_i	0.32	0.40 cm^2

$$\sum_i \frac{L_i}{K_i A_i} = 39 \frac{K}{W}$$

$$\Rightarrow \quad \Delta T = 2.2W * 39 \frac{K}{W} = 86 \text{ Kelvin}$$

At border of W, $T = 86 + 27 = 113^\circ C$

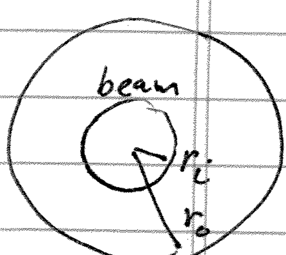
Warning! $T_{melt}^{Al} = 933^\circ C$

So, if $I \gtrsim 11 \mu A$, Alum melts.

Next, consider the tungsten
$k = 2.0 \frac{W}{mK}$

Analytical estimate

$$\Delta T = \frac{P}{2\pi k t} \ln \frac{r_o}{r_i}$$



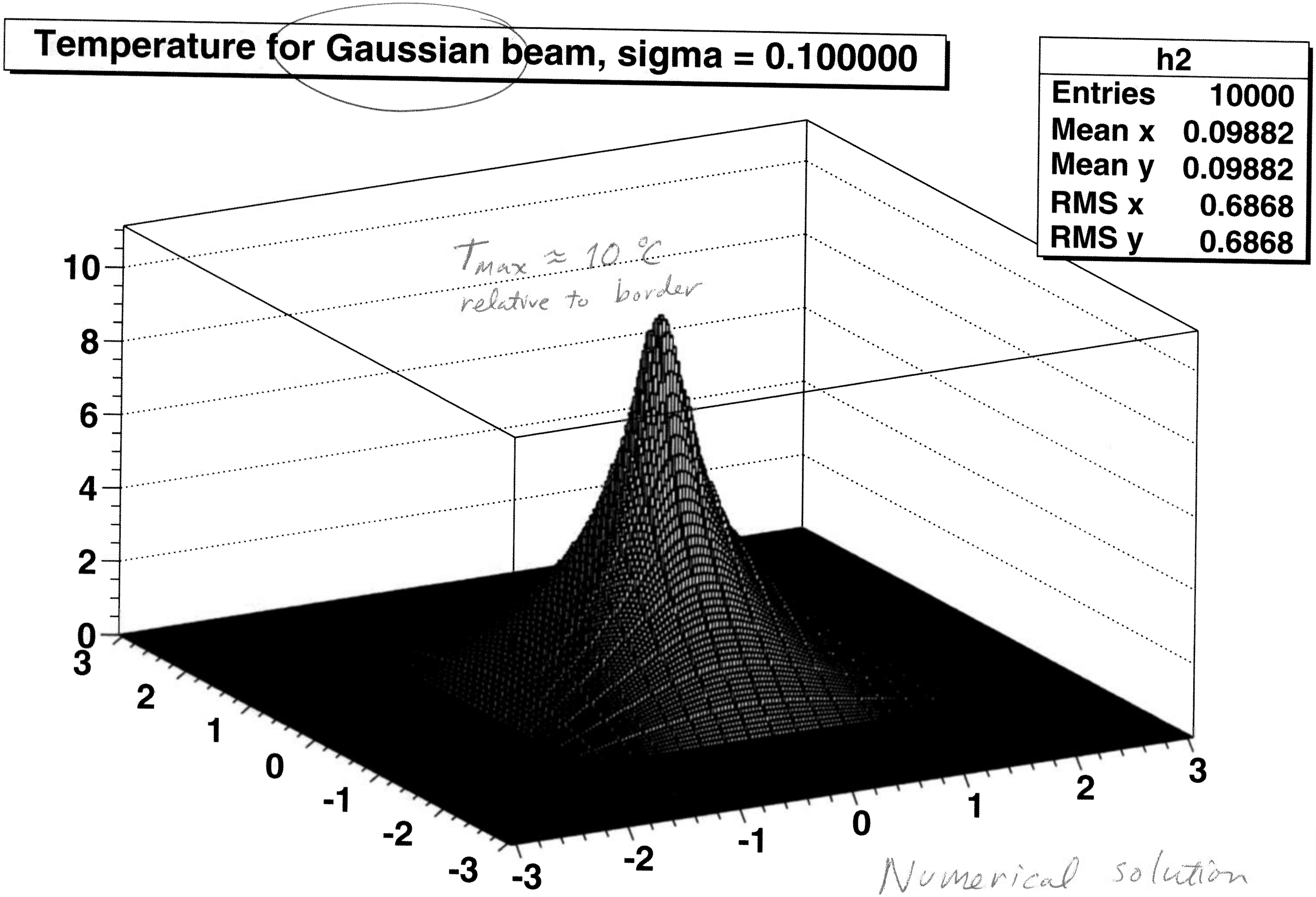
$P = 2.2W$ $\quad$ $k = 2.0 \frac{W}{mK}$ conductivity $\quad$ t = target thickness, 0.1 cm

$r_o = 2.54\text{cm}$ target size $\quad$ $r_i = 0.1\text{cm}$ beam size

$$\Rightarrow \Delta T = 6^\circ c$$

Numerical solution to heat equation agree for Gaussian or uniform beam profile.

$I = 1\,\mu A \quad t = 0.1\,cm \quad P_b = 2.2\,W$



Numerical solution to heat eq'n

20k iterations; convergent in ~1k ite

$I = 1\,\mu A \quad t = 0.1\,cm \quad P_b = 2.2\,W$